SCIENCE STANDARD 9

All students will gain an understanding of natural laws as they apply to motion, forces, and energy transformations.

INTRODUCTION

This standard forms the basis for an investigation of force and motion leading to an understanding of energy and energy transformation. By studying moving objects and the forces (visible and invisible) that cause them to move, students develop an understanding of the fundamental laws of motion along with the notion of kinetic and potential energy. All forms of radiant energy—such as heat, light, and sound—are simultaneously explored, first as observable phenomenon and eventually as qualities that can be described and measured mathematically. Key to the achievement of this standard is an understanding of the factors affecting the production, transfer, and conservation of energy.

DEVELOPMENTAL OVERVIEW

In grades K-4, a young child's world is a world of objects that are compared, described, and manipulated. Pushing, pulling, and dropping objects leads to an intuitive sense of what causes and controls motions, although the concept of motion is elusive at this age. Likewise, sources of heat, light, sound, electricity, and magnetism can be experienced and experimented with. At these grade levels, heat will not be distinguished from temperature, and the notion of action at a distance—forces such as magnetism, static electricity, and gravity—can be observed but not understood.

By grades 5-8, descriptions of motion can move from qualitative to quantitative, involving the determination and even the calculation of speed. Discussing the factors affecting speed will introduce the force of friction, which will be somewhat misunderstood as the concept of inertia begins to develop. The idea of energy will begin to take root, linked first with the motion of objects (mechanical energy). Continuing investigations of heat, light, sound, electricity and magnetism, and gravity will contribute to a more conceptual understanding of energy as something that has many forms and is constantly being transferred.

By grades 9-12, students are ready to deal with force, motion, and energy as phenomena that can be measured, calculated, and compared using mathematical expressions and equations. Laboratory investigations and descriptions of other experiments can help them understand the evidence leading to the laws of motion and the conclusion that energy is conserved. At this age, experiences should do more than confirm physical laws and principles. Students should be confronted with technological design problems where they can observe firsthand—and put to use—those principles and concepts associated with energy transfer.

DESCRIPTIVE STATEMENT

Basic principles of physics emerge in this standard, where the study of force and motion leads to the concept of energy. All forms of energy are introduced and investigated, and principles of transformation and laws of conservation are developed.

CUMULATIVE PROGRESS INDICATORS

By the end of Grade 4, students

1. Demonstrate that the motion of an object can vary in speed and direction.
2. Demonstrate that the position and motion of an object can be changed by pushing or pulling and that the change is related to the strength of the push or pull.
3. Recognize that some forces are invisible and can act at a distance.
4. Investigate sources of heat and show how heat can be transferred from one place to another.
5. Investigate sources of light and show how light behaves when it strikes different objects.
6. Demonstrate how sound can be produced by vibrating objects and how the pitch of the sound depends on the rate of vibration.
7. Demonstrate how electricity can be used to produce heat, light, and sound.

Building upon knowledge and skills gained in the preceding grades, by the end of Grade 8, students

8. Explain how a moving object that is not being subjected to a net force will move in a straight line at a steady speed.
9. Show that when more than one force acts on an object at the same time, the forces can reinforce or cancel each other, producing a net force that will change the speed or direction of the object.
10. Investigate how the force of friction acts to retard motion.
11. Describe the various forms of energy, including heat, light, sound, chemical, nuclear, mechanical, and electrical energy and that energy can be transformed from one form to another.

12. Explain how heat flows through materials or across space from warmer objects to cooler ones until both objects are at the same temperature.

13. Explain that the sun is a major source of the Earth's energy and that energy is emitted in various forms, including visible light, infrared and ultraviolet radiation.

14. Show how light is reflected, refracted, or absorbed when it interacts with matter and how colors appear as a result of this interaction.

15. Show how vibrations in materials can generate waves which can transfer energy from one place to another.

Building upon knowledge and skills gained in the preceding grades, by the end of Grade 12, students

16. Explain the mathematical relationship between the mass of an object, the unbalanced force exerted on it, and the resulting acceleration.

17. Prove that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object.

18. Know that gravity is a universal force of attraction between masses that depends on the masses and the distance between them.

19. Know that electrically charged bodies can attract or repel each other with a force that depends on the size and nature of the charges and the distance between them.

20. Explain the similarities and differences between gravitational forces and electrical forces that act at a distance.

21. Know that the forces that hold the nucleus of an atom together are stronger than electromagnetic forces and that significant amounts of energy are released during nuclear changes.

22. Explain how electromagnetic waves are generated, and identify the components of the electromagnetic spectrum.

23. Explain that all energy is either kinetic or potential and that the total energy of the universe is constant.

LIST OF LEARNING ACTIVITIES FOR STANDARD 9

GRADES K-4

Indicator 1:

GRADES K-2
Moving Objects

GRADES 3-4
Bike Riding
Rolling Objects down a Ramp
Marble Maze

Indicator 2:

GRADES K-2
Playing Tug-of-War
Flying Kites

GRADES 3-4
Arrows Represent Forces
Using an Inclined Walkway
Moving Toys
The Force of Wind

Indicator 3:

GRADES K-2
Magnet on Toy Car
Paper Clip on Thread
Magnetic vs. Nonmagnetic Classification

GRADES 3-4
Demonstrating Magnetic Fields
Magnetized Needle
Static Electric Fields
Gravitational Fields
Building Electromagnets
Compass Investigation
Falling Objects

Indicator 4:

GRADES K-2
Fluids in Motion
Heat Lamp
How Animals Keep Warm

GRADES 3-4
Air Currents
Chemical Sources of Heat
Partner Convection Experiments

Indicator 5:

GRADES K-2
Light Mystery Box
Different Color Lightbulbs
Totally Dark Room
Seeing through Rose-Colored Glasses
Mirror Cards
Light Striking Various Surfaces
Heating of Materials by Sunlight

GRADES 3-4
Water Drop Experiments
Light Beams
Colored Goggles
Convex and Concave Mirrors
Convex and Concave Lenses

Indicator 6:

GRADES K-2
Rubbing a Comb
Feeling Vibrations
Making Musical Instruments

GRADES 3-4
Seeing Sound Vibrations
Seeing Sound Waves
Making or Transmitting Sound

Indicator 7:

GRADES K-2
Speaker and Sound
Producing Heat with Electricity

GRADES 3-4
Nichrome Wire Experiments
Simple Circuit
Buzzers

GRADES 5-8

Indicator 8:

GRADES 5-6
Toy Car

GRADES 7-8
Inertia

Indicator 9:

GRADES 5-6
Tripod Pendulums
Modes of Transportation
Forces on an Airplane
Fluid Pressure

GRADES 7-8
Car Loop
Simple Machines

Indicator 10:

GRADES 5-6
Overcoming Friction
Parachute Car

GRADES 7-8
Surface Friction

Indicator 11:

GRADES 5-6
Energy and Communications Technology
Lewis Latimer

GRADES 7-8
Energy Transfer
Mall Physics
Power Plant Role-Play

Indicator 12:

GRADES 5-6
Heat Transfer

GRADES 7-8
Energy Efficiency
Freezing Water

Indicator 13:

GRADES 5-6
Solar Energy
The Greenhouse Effect

GRADES 7-8
Energy Technology
Energy Conservation
Receiving Wavelengths

Indicator 14:

GRADES 5-6
Periscope
Mirrors

GRADES 7-8
Lenses
Underwater

Indicator 15:

GRADES 5-6
Sound Travel through Solids
Sound Travel through a Liquid
Sound Travel through a Gas

GRADES 7-8
Straw Oboes
Straw Pipes

GRADES 9-12

Indicator 16:

Newton's First Law of Motion
Newton's Second Law of Motion

Indicator 17:

Newton's Third Law of Motion

Indicator 18:

Gravity and Distance

Indicator 19:

Electrostatics

Indicator 20:

Gravitational and Electrostatic Forces

Indicator 21:

Nuclear Physics

Indicator 22:

X Rays
Color
Uses of Electromagnetic Radiation
EMFs

Indicator 23:

Toys and Energy
Bouncing Balls
Heat Exchange

Indicator 1: Demonstrate that the motion of an object can vary in speed and direction.

LEARNING ACTIVITIES: Grades K-2

Moving Objects. Students assemble a variety of objects such as the following:

- things they can roll (e.g., toy cars)
- things they can drop (e.g., two pieces of paper, one kept flat and the other crumpled up in a ball)
- animals (including some humans)

After discussing safety issues related to movement, speed, and impacts, students allow the objects to move and then compare their movements. Challenge the students to answer questions like the following:

- Which piece of paper falls faster?
- How are the movements of those two objects alike? How are they different?
- Which toy car goes faster?
- What would be a fair test to determine which of the two toy cars goes faster?

Discuss with students how they can decide which one goes faster. Many students will feel that the car that travels farthest goes faster. This is not always true. Students will learn that the speed of an object depends not only on how far the object goes (*distance*) but also on the *time* it takes to go that distance.

Ask the students to try to make each car go faster or change its direction. By experimenting, students should conclude that a push or a pull (i.e., a *force*) is needed to change speed or direction.

Reading the story about the tortoise and the hare would be a good literature connection.

Supporting Educational Research: *Benchmarks*, p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.12, 3.7, 5.3

LEARNING ACTIVITIES: Grades 3-4

Bike Riding. Ride a tricycle or small bicycle in class. (The sillier you look, the better students will remember the ideas!) Discuss how you can vary the speed and direction, do it, and then ask questions such as

- Can I make myself stop?
- How fast can I go?
- Will it be harder to stop if I go faster?
- How can I cover the longest distance in the shortest time?
- How much of a ramp can I go up?

The intent is to help students examine what caused the motion and what has to happen to change any motion. Ask students to describe what they see happening. They can then set up experiments as appropriate. Discuss safety issues related to movement, speed, and impact.

Rolling Objects down a Ramp. Working cooperatively in groups, students take pieces of wood (about 2 ft by 4 ft) and make ramps, using books to prop up the wood pieces. They roll a can, model car, or ball down the ramp after predicting about how far the object will go. They keep records of actual distance covered and the time it took to cover that distance. Next, the students increase the angle of the ramp. They allow the can (or car or ball) to roll once more, again keeping records. As they increase the angle, the object rolls farther in less time. Once students realize the relationship between distance and time, discuss the concept of speed. Also discuss safety issues related to movement, speed, and impact.

Marble Maze. This challenge focuses on the concepts of motion, gravity, and the controlling of speed and direction. Give each group of students a board (approximately 2 ft by 4 ft). Ask them to design and construct a ramp on which a marble will roll from a high point to a low point. By adding hills, valleys, and other obstacles, they must cause the marble to take the longest possible time to roll from the top of the ramp to the bottom. Students keep a design journal throughout the activity to record their actions as well as design successes and failures.

Supporting Educational Research: Benchmarks: p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.12, 3.2, 4.2, 5.3

Indicator 2: Demonstrate that the position and motion of an object can be changed by pushing or pulling and that the change is related to the strength of the push or pull.

LEARNING ACTIVITIES: Grades K-2

Playing Tug-of-War. As students play tug-of-war, point out that if both teams pull equally hard, the rope does not move. Discuss how forces must be uneven to cause a change in movement. Be sure to use a strong enough rope and follow safety procedures.

Flying Kites. Students' kite flying dramatically shows the effects of wind as a force that can change the motion of an object. Students can use a simple fan to help them design small kites. They use weather forecasts to identify days in the coming week that might be best for kite flying. In this way, a study of forces and motion can be related to their understanding of weather.

Supporting Educational Research: Benchmarks: pp. 89, 94
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 5.3, 5.4

LEARNING ACTIVITIES: Grades 3-4

Arrows Represent Forces. Draw diagrams using arrows to indicate the direction of each obvious force acting on an object. The length of each arrow indicates the amount of the force. The longer the arrow, the greater the force. Ask the students questions such as the following:

- What can you tell about the forces on an object that is sitting still?
- What happens if the object is already moving and the forces are equal in all directions?

Write a series of examples on the board using arrows representing all possible forces pushing on a box. Let students determine whether the object will move and in what direction. A simple computer simulation program would be useful.

Using an Inclined Walkway. Have students try to push or pull a loaded wagon up an inclined walkway. Let them experiment with different loads to determine the amount of effort needed to push or pull the wagon up the walkway. Students should come to realize that a change in force makes a substantial difference in movement. Ask the students whether or not there are forces on

- an object that is standing still (e.g., halfway up the ramp)
- an object that is moving

Supporting Educational Research: Benchmarks: pp. 89, 94
Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.9, 3.10, 4.2, 5.4

Moving Toys. Each student brings in a moving toy from home. Working in groups, the students analyze how each toy moves.

- Does it have wheels?
- Do some of its parts move?
- Where does the energy for the toy's movements come from?
- How are the toy's movements similar to how people move?

Students discuss the toy's movements and develop a short oral/visual presentation explaining how their toy moves.

After these presentations are made, draw the students' attention to the different ways the toys move. Some are wind-up toys, some need batteries, and some are operated by hand.

Next, students design and make their own moving toys using plastic drinking straws, brass fasteners, cardboard, and other everyday materials. Challenge them to make their devices move up and down as well as from side to side without directly touching the toy. For example, a balloon fastened over the top of a plastic soda bottle will inflate and make the toy move when the bottle is squeezed.

Supporting Educational Research: Benchmarks: pp. 89, 94
Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.9, 3.10, 4.2, 5.4

The Force of Wind. The push or pull of the wind is often difficult for students to see in the same way that they can see other forces acting. The following two activities are designed to show that the wind's force is real and measurable.

Students create a wind-powered pulley by following these steps:

- First, they place a thread spool onto a pencil axle.
- They design fan blades and fasten them onto the spool.
- Then they tie one end of a piece of thread to a paper clip and fasten the other end of the thread to the spool so that the thread winds up as the spool turns.
- Students point a hair dryer at the fan blades to make the spool turn, thus winding up the paper clip. (They will need to standardize the distance of the hair dryer from the blades. Advise them to use the coolest temperature setting possible).

Ask students to predict the blade design and the hair dryer blower speed that will make the spool turn to lift up the paper clip in the shortest time. They can set up experiments to test these predictions.

Students figure out the best parachute design that will keep five pennies (or whatever weight they choose) in the air for the longest period of time.

Supporting Educational Research: Benchmarks: pp. 89, 94
Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.9, 3.10, 4.2, 5.4

Indicator 3: Recognize that some forces are invisible and can act at a distance.

LEARNING ACTIVITIES: Grades K-2

Magnet on Toy Car. Students place a magnet on a small plastic car. When they bring another strong magnet near the car, the car should move—even though the two are not touching. Challenge the students to predict what will happen if they bring the different poles of magnets near each other. As they set up assorted experiments, they describe what they think is happening. Is the force going through the air? Confirm their correct explanations and correct their misconceptions.

Paper Clip on Thread. After tying a thread onto a paper clip, have students hold a magnet in the air near the clip. The clip will rise into the air. After students make some predictions, they place thin objects between the clip and the magnet. They try to answer questions such as the following:

- What materials seem to affect the force?
- What is the effect of the distance between the clip and the magnet on the ability of the magnet to hold the clip in the air?

Magnetic vs. Nonmagnetic Classification. Students classify objects as *magnetic or nonmagnetic*. Ask them what characteristics the magnetic objects appear to have in common. (Be sure to include enough samples of each type.)

Supporting Educational Research: Benchmarks: p. 94
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.6, 3.10

LEARNING ACTIVITIES: Grades 3-4

Demonstrating Magnetic Fields. Put a bar magnet under a transparency sheet on an overhead projector, and sprinkle iron filings on the sheet. Place various poles together to create different patterns as the iron filings arrange themselves along the lines of force in the fields. Explain the term field as needed.

Students can do a similar activity, working carefully with the iron filings. One way of keeping the filings from getting all over is to place them in Petri dishes and tape the dishes closed. However, the container may be hard to use with normal bar magnets. Cylindrical magnets are smaller and may be more appropriate for this activity.

To show that a magnetic field is three-dimensional, carefully place a cow magnet into a test tube that is secured inside a larger jar containing many iron filings. (Cow magnets are magnets fed to cows to attract any pieces of metal the cow eats so the metal does not harm the cow.) Gently shake the jar. The iron filings will attach themselves to the test tube, showing that something is clearly all around the magnet. Students will also be interested in why cow magnets are given to cows and their impact on the farming industry.

Magnetized Needle. Float a large magnetized needle on a small piece of cork in water. The needle always moves in a certain direction. Have students note its direction. Compare with a compass needle.

Supporting Educational Research: Benchmarks: p. 94
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 1.3, 2.6, 3.7, 3.15

Static Electric Fields. Students design and conduct different static electricity experiments. They can easily create a charge by rubbing a strip of transparency sheet with plastic "cling" wrap. After repeating this action with a second strip of transparency sheet, they bring the two identically charged materials together. What happens? Next, students create two other charges by rubbing strips of transparency sheets with wool. What happens when these two strips are brought together?

Finally, students bring the transparency strip rubbed with plastic wrap near a piece of transparency sheet rubbed with wool. What happens? Students compare and contrast all these actions with magnetic fields.

Gravitational Fields. Have students hold a book or other unbreakable object about one foot above the floor and predict what will happen if they let it go. What if the object is dropped from a stepladder? What if it is dropped from a second-floor window? Is there some height at which their predictions would change? Discuss what is causing the effect, and explain that the effect continues even when the object hits the ground. Students will begin to see that gravity is more than just the weight of an object on the surface of the Earth and will begin to understand the nature of gravitational fields.

Supporting Educational Research: Benchmarks: p. 94
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 1.3, 2.6, 3.7, 3.15

Building Electromagnets. Students build an electromagnet and discover that there is a force in the electromagnet that repels or is attracted to a magnet. Students identify the factors that can determine the amount of movement. They show that the electromagnet can pick up things that were not touched in the beginning. (*Caution:* Only touch wires to a battery momentarily; otherwise, wires will get *hot*. Be sure to follow appropriate safety precautions.)

The class can hold a contest to design the best electromagnet. In small groups, students list all the factors they think may affect the strength of electromagnets and then test each one to find the best design for each factor. They combine all the best designs into the electromagnet they will use in the contest to pick up the greatest number of paper clips.

Compass Investigation. Students investigate how a compass reacts to weak and strong magnets. Each student balances a bar magnet hanging on a thread. In what direction do all the bar magnets seem to point? What does this suggest? (*Note*: It may be necessary to move students apart from each other so the individual magnets do not affect each other.)

Falling Objects. Students discover which shapes allow objects to fall faster than other shapes. They design experiments in which the weight of objects is kept constant, but the shape is changed. Next, they use another set of objects in which the shape is the same but the weight varies.

Supporting Educational Research: Benchmarks: p. 94
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.15, 4.5, 5.4

Indicator 4: Investigate sources of heat and show how heat can be transferred from one place to another.

LEARNING ACTIVITIES: Grades K-2

Fluids in Motion. Students set up various types of convection experiments to simulate ocean movement, air currents, and other fluid motions. (Remind them to use normal safety procedures regarding goggles.)

- They place a drop of food coloring in one end of a container of water being heated by something hot. What happens?
- They place open baby-food jars of very warm water, cold water, and room-temperature water into an aquarium of tap water at room temperature. What happens?
- They place drops of food coloring in very warm water and also in cold water. What differences occur in the motion?

Heat Lamp. Turn on a heat lamp at least 10 feet away from students. Students predict and then time how long it takes for the heat to reach them. Can they detect the heat in the back of the room?

Take a cookie sheet or a piece of cardboard covered with aluminum foil and bend it into a curved mirror. Students discover they can bounce the lamp's heat rays off the cookie sheet or foil-covered cardboard. They can investigate what type of surface absorbs or reflects the most heat. Encourage students to see similarities with how sound moves. (*Note*: The differences between sound and light will not be apparent with these experiments.)

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.6, 3.9, 5.7

How Animals Keep Warm. What do animals do that helps them stay warm? In the following activities, students study the features that protect animals from the cold.

- Students put some vegetable shortening or lard (to represent the fat on an animal's body) on a finger, which they then place in cold water. As a control, they put another finger in cold water and compare the amount of cold each finger feels.
- Students place a finger in a balloon partially filled with air. This balloon represents an animal's oily surface, which keeps water from its skin. They immerse the finger in cold water and compare how this finger feels in cold water with another finger also in cold water.
- Students wrap a finger with cotton to simulate a fur-bearing animal's protection from extreme temperature. They place that finger in ice and then in ice water. They compare and contrast what happens to this finger with what happens to an unprotected finger.

Discuss with the students how they keep warm. Include in your discussion mention of the following:

- layering
- type of material
- color (dark vs. light)
- function of hats and gloves

Challenge students to determine how many layers of newspaper are required to keep a small jar of ice from melting for one hour and for the whole school day.

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.6, 3.9, 5.7

LEARNING ACTIVITIES: Grades 3-4

Air Currents. Using thin pieces of tissue paper, students look for air currents in their classroom. Suggest that they check by the bottoms of doors and near windows. Have a big pot of warm water and another big pot of cold water in the classroom. Using the movement of tissue paper as an indicator, students determine in what direction the air is moving around the pots. Discuss the implications of what they discovered.

Chemical Sources of Heat. In this activity, students discover that some chemical reactions produce heat. Wearing goggles and following appropriate safety precautions, they place a small amount of calcium chloride (road salt) pellets in a cup. They carefully place the cup into a sealable plastic bag containing some water and then close the bag. Students carefully mix the items and notice the amount of heat that is produced. Demonstrate commercially sold cold and hot packs to the students as examples of a practical application.

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9

Partner Convection Experiments. In groups of two, students fill a baby-food jar with cold water and place a laminated index card over the jar. Holding the card on top of the jar, one of the students of each pair turns the jar over. The card will stay on the jar.

The partner fills another jar of the same size with cold water. Since this is a bottom jar, the jar must be filled to the very top. The student adds some food coloring to the water in the jar.

Working in a deep plastic tray, the students place the first jar precisely on top of the bottom jar and then slide out the laminated card. They observe what happens, determining the movement of the water by watching what happens to food coloring. Does the water move? (*Note*: The bottom jars must be totally full or students will see motion caused by the water dropping, not by any other cause.) The student partners repeat the procedure with various combinations of water, e.g., hot over hot, warm over warm, hot over cold, and cold over hot.

Students keep records of their observations. At some point, they should be able to explain the patterns of movement and answer questions such as the following:

- When does the most movement occur? The least movement?
- What does this suggest about movement of water in the oceans or ponds or even in a sink?
- What happens if salt water is used?

Discuss sources of heat with the students and demonstrate some (such as the following) with student participation.

- Rub hands together (heat by friction).
- Use a hot plate (heat due to electrical resistance).
- Bend a coat hanger back and forth (also showing heat due to friction).
- Light a match (following safety requirements regarding goggles and fire extinguisher).

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9

Indicator 5: Investigate sources of light and show how light behaves when it strikes different objects.

LEARNING ACTIVITIES: Grades K-2

Light Mystery Box. Set up a mystery box with only a dime-size hole in it. Place brightly colored pieces of paper inside. What colors do students see? Ask the students to compare the way the papers look inside the box with the way they look outside the box.

Different Color Lightbulbs. Students look at various objects in normal room lighting, noticing their color. Darken the classroom and shine lightbulbs of different colors (one at a time) on the objects. Ask students to describe what seems to happen to the color of objects as lightbulbs of different colors illuminate the objects.

Totally Dark Room. In a totally dark room hold up a piece of paper and ask students to describe what color paper it is. They will not be able to tell. Next, use a very dim light. The students will see objects, but no color. Discuss how humans see things.

Seeing Through Rose-Colored Glasses. In this activity, have students wear goggles covered with two pieces of red cellophane. Place toothpicks of different colors on the floor. Ask the students to pick up toothpicks of any color except green. After one or two minutes, they count how many non-green toothpicks they picked up. Discuss why green toothpicks appear black when viewed with red-covered goggles. The fact that many animals cannot see all colors can lead to an interesting classroom discussion.

Mirror Cards. Have students play "mirror cards" in which a mirror is used to complete a drawing. For example, if students have half a butterfly, how would they use a mirror to show the whole image? If they have three triangles arranged in a pattern, how could they use a mirror to reverse the image? The designs can range from beginner to very advanced, in which students use two or more mirrors to create the final drawing.

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.7

Light Striking Various Surfaces. Students allow a light to go through or strike a variety of flat and curved surfaces. What do they notice happening to the light? For example, if students shine a light on flat mirrors and flat glass, what happens?

Heating of Materials by Sunlight. Allow sunlight or a properly protected lamp to shine on the following items and determine which becomes warmer.

- Set 1: Bowls of water with different colors of paper under the bowls
- Set 2: Bowls of colored water
- Set 3: Different color sands
- Set 4: Soils of different texture

Students observe and discuss what seems to be happening.

What happens to the light coming from the sun when it reaches the Earth? Use a globe to enhance the discussion.

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.7

LEARNING ACTIVITIES: Grades 3-4

Water Drop Experiments. Working cooperatively in small groups, students attempt to figure out what size and shape of a water drop magnifies an image the most. They use an eyedropper to place drops of water on waxed paper over newsprint. Students look at a side view of each drop to see the shape of the drop. They relate the shape and size of the drop to its magnification.

Light Beams. Pass a thin beam of light through a piece of diffraction grating or prism. (A specially made slide with a thin slit works well in a slide projector to produce a thin beam of light.) A spectrum should appear on the wall or a piece of paper depending on position. Ask students which conditions result in the clearest spectrum or the thickest spectrum. When is a spectrum not visible? Discuss where the colors of the spectrum come from.

Students position a piece of diffraction grating or prism at one end of a tube. When they hold the tube up to a classroom light, they will see the spectrum. Further investigations could be to examine bulbs of different colors. Are there differences? *Caution:* Students should avoid looking directly at the sun or at sunlight reflected in a mirror.

Next, students can investigate what parts of the spectrum become visible when lightbulbs of different colors are used.

Colored Goggles. Students make goggles from the plastic rings that are used to hold a six-pack of soda cans together. They can make two sets from each six-pack. For lenses, they fasten various colors of cellophane (one color at a time) onto the goggles. Working with a partner, they view a set of at least five pieces of paper of different colors. Students record their findings and compare how each color of paper looked when viewed through each color of lens. Ask the students questions such as the following:

- Which lens made which color is the brightest?
- Did any color seem not to be affected by the color of the lens?

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.7, 4.2

Convex and Concave Mirrors. Students can create convex or concave mirrors in one of two ways:

- They carefully place shiny aluminum foil on the inside or outside of large bowls.
- They bend disposable cookie sheets to form the mirrors. If they use cookie sheets to form concave mirrors, they will be a ble to bend the sheet to focus the light at various locations.

Next, students shine light on these convex or concave mirrors and describe what happens.

Convex and Concave Lenses. Have students collect lenses from old eyeglasses, magnifying glasses, etc. How do objects appear when viewed through the different lenses? Do all lenses have the same shape? Are they all made of the same material? Have students make their own lens by filling a clear glass jar with water or another clear liquid. A discussion of why some people need eyeglasses could include an explanation of the lenses in the human eye.

Supporting Educational Research: Benchmarks: pp. 83-84
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 3.3, 3.7, 4.2

Indicator 6: Demonstrate how sound can be produced by vibrating objects and how the pitch of the sound depends on the rate of vibration.

LEARNING ACTIVITIES: Grades K-2

Rubbing a Comb. Students rub a comb over an edge. As they increase the speed at which the teeth hit the edge, the pitch goes up.

Feeling Vibrations. In the following activities, students have the opportunity to feel vibrations.

- Place objects inside coffee cans with lids. As students shake the cans, they hear the difference in the sounds of various objects and feel the vibrations.
- Students hold their hand on their vocal cords and feel the vibrations as they talk.
- Students hold their hand on a speaker of a stereo system. They note the difference in vibration as the speaker reacts to changes in volume and pitch of the music.

Making Musical Instruments. Working in groups, students brainstorm as many sounds as possible. Why do these things make noise? Discuss the nature of sound, introducing the concept of vibration.

Demonstrate (or ask students to demonstrate) how a variety of instruments are played. Include examples of percussion, reed, and stringed instruments. As a class, discuss how the instruments are designed. Encourage students to design their own instruments using a variety of recycled materials. (Teacher-made examples would be useful.) If time permits, students can tune some of the string and percussion instruments (e.g., glass jars filled with water) to specific notes and play some simple, familiar songs.

Supporting Educational Research: *Benchmarks,* p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 1.3, 3.2

LEARNING ACTIVITIES: Grades 3-4

Seeing Sound Vibrations. Cut off both ends of a can. Cover one end of the can with a tightly stretched balloon. Glue a small, lightweight mirror or a flat piece of shiny aluminum foil to the middle of the outside of the balloon. Shine a light onto the shiny surface, which will make a spot of light on the wall or ceiling. Students make sounds into the open end of the can to discover the effect on the pinpoint of light on the wall or ceiling. What happens to the movement of this light spot as they make sounds of different pitches or loudness?

Seeing Sound Waves. This activity enables students to “see” sound waves. Set up an oscilloscope with a microphone. Because each pitch produces a different wave, it will be relatively easy to identify students through their unique wave patterns of the same sound. Each pitch can be given a number. The music teacher can loan or demonstrate tuning forks, all of which have a number indicating their vibrations per second. Frequently, local research firms will be glad to send in an older oscilloscope and someone to demonstrate its use in making sound visible.

Videodiscs are available showing short clips on pitch; time-lapse pictures of vibrating objects, including the vocal cords; and pictures of sound waves on oscilloscopes.

Supporting Educational Research: *Benchmarks,* p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 2.7, 3.4, 4?

Making or Transmitting Sound. Set up a series of tasks for small groups of students to complete. Sample tasks include the following:

- Determine what thickness, tension, and length of rubber bands give the highest pitch.
- Set up bottles with different levels of water, and play a tune by blowing into each bottle.
- Build a string telephone that works.
- Determine what materials make the clearest string telephone that can carry sound over 20 ft.
- Design a string telephone that will work around a corner.

Students complete each activity at their own speed, checking their procedures and conclusion with the teacher. Each student is then held accountable for being able to demonstrate and explain what was done to solve the problem.

Supporting Educational Research: *Benchmarks,* p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 2.7, 3.4, 4

Indicator 7: Demonstrate how electricity can be used to produce heat, light, and sound.

LEARNING ACTIVITIES: Grades K-2

Speaker and Sound. Any speaker will show that an electrical flow can produce sound. As students hold their hand on a speaker, they feel a difference as the volume changes and as the pitch changes.

Producing Heat with Electricity. Toasters and lightbulbs obviously give off heat. (In fact, almost anything electrical produces heat.) Students can feel the heat and measure the rise in temperature by bringing a thermometer near each device. (Be sure to follow all appropriate safety procedures!)

Supporting Educational Research: *Benchmarks,* p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 5.1, 5.4

LEARNING ACTIVITIES: Grades 3-4

Nichrome™ Wire Experiments. Students set up experiments with #32 Nichrome wire in a simple circuit with a light bulb to discover how the wire affects the brightness of the lightbulb. They determine the effects of increasing the length of the Nichrome wire and its diameter (just wrap more wire together) on the brightness of the bulbs. A thin piece of aluminum foil will get hot enough to melt if placed in the circuit without the lightbulb. The Nichrome wire will also get hot under certain conditions, so caution students in its use. Discuss how bad or improperly installed wiring in homes or other buildings is a potential cause of fires. Invite a city/town building inspector to address these issues.

Simple Circuit. Students investigate simple circuits using several lightbulbs and one battery. Next, they study the differences between what happens to the bulbs when they are wired in series and when they are wired in parallel. Students can also determine the effect of placing batteries in series (only one or two—more than two will probably burn out the bulbs) or in parallel (any number of batteries will be fine).

An electrician could be invited to discuss with the class how homes are wired, why switches are used, and so on.

Buzzers. Student groups may be able to construct buzzers using wire, nails, a block of wood, pieces of metal, and a battery. After figuring out how to control the pitch and loudness of the sound produced, they apply this knowledge to create a Jeopardy™ game or game board.

Supporting Educational Research: *Benchmarks,* p. 89
Related Science Standards: 2, 4, 5, 9
Related Workplace Readiness Standards: 1.3, 5.6

Indicator 8: Explain how a moving object that is not being subjected to a net force will move in a straight line at a steady speed.

LEARNING ACTIVITIES: Grades 5-6

Toy Car. How far will a toy car roll? Using a variety of toy cars, students experiment to see how far they can get a car to roll. They attempt to answer questions such as the following:

- Can the car roll forever? Why not?
- What are the forces acting on the rolling car?
- What would happen if the force of friction could be totally eliminated?

Some students who may already have experienced designing cars for "derby" competitions should be a valuable resource.

Related Science Standards: 2, 5

LEARNING ACTIVITIES: Grades 7-8

Inertia. In order to learn about inertia, students compare the factors at work in a system of inclined planes and sudden stops. Student groups construct inclined planes of various heights on which they release a toy car. On each toy car, students place a clay person that moves with the car. At the bottom of the ramp, they place a broad straightaway with a structure low enough to stop only the car.

Students attempt several trials at each height and determine the average "flying" distance for the clay person. They graph the car's data (distance and time) and compute the speed of the car for each attempt.

Changing the surface of the straightaway and/or the inclined plane could be used as a follow-up lesson on potential energy and friction.

Related Science Standards: 1, 2, 4, 5

Indicator 9: Show that when more than one force acts on an object at the same time, the forces can reinforce or cancel each other, producing a net force that will change the speed or direction of the object.

LEARNING ACTIVITIES: Grades 5-6

Tripod Pendulums. Working in groups, the students construct freestanding (tripod) pendulums with a small magnet as a bob. They swing the pendulum and trace its path in pencil as it swings. At the bottom of the tripod, the students place several small magnets, one at a time, near the pendulum's path. They observe any change in the path. Students move the magnets and predict the new path, explaining what force(s) will change the path.

Related Science Standards: 2, 4, 5

Modes of Transportation. Students bring in toys or models that represent different modes of transportation on land, on water, and in the sky. They group the toys by method of movement and then examine each type:

- Land transportation—Students examine their models and use them to sketch diagrams. They draw arrows to show the forces acting on each vehicle when it is (a) moving along a level highway, (b) going uphill, (c) going downhill, and (d) parked.
- Water transportation—Similarly, students diagram the forces acting on boats. Different means of propulsion (paddles, oars, sails, etc.) as well as the effect of water currents add to the challenge of the task.
- Air transportation—Students once again analyze the forces acting on airplanes, balloons, helicopters, etc. as they explore the dynamics of flight. A discussion and demonstration of how an airplane changes direction should be part of this activity.

Related Science Standards: 1-5

Forces on an Airplane. A paper airplane contest is ideal for an introduction to a forces discussion.

First students construct identical paper airplanes and compare throwing forces and techniques. Then they create airplanes of different designs and hold an "open" contest, in which they vary the airplanes' path, speed, distance, and hang time.

Fluid Pressure. The forces exerted by fluids must often be considered when studying all of the forces acting on an object. Students can easily demonstrate the idea of moving-fluid pressure by using paper-airplane wings and/or Ping-Pong(balls.

- Students construct an airplane wing of paper and blow above, below, and directly at the wing to determine the best design and angle.
- Students place a Ping-Pong ball in a beaker (or cup) and blow over the beaker. They then measure the height of the ball as it moves upward in the beaker.

Related Science Standards: 1, 2, 4

LEARNING ACTIVITIES: Grades 7-8

Car Loop. Students construct a loop using plastic track. They propel toy cars on the track by rolling them, using an inclined plane, and/or using a spring-loaded propulsion device. After several practice shots, the students collect data on the following:

- mass of the car
- height of the incline
- distance traveled
- time needed for the journey.

Using the data collected, students determine the average speed, minimum speed, and minimum incline needed to propel the car through the loop. They attempt to answer questions such as the following:

- What factors or forces altered the car's journey?
- Why did some cars fail to complete the loop?
- Which cars were successful most often and why?

Have students demonstrate other objects that move in a circle. Discuss the force(s) that keep things moving in circles, such as the planets moving around the sun.

Related Science Standards: 1, 2, 4, 5, 11

Simple Machines. Students investigate the concepts of force, fulcrum, and resistance by first researching how humans have used simple machines throughout history.

Small groups of students cooperatively construct a simple machine such as an inclined plane, pulley, or lever. Using their machine, the students perform a specific task such as moving a bookcase, lifting a desk, or pushing a chair. After all the groups test their simple machines, they make a presentation to the entire class.

Related Science Standards: 1, 2, 4, 5

Indicator 10: Investigate how the force of friction acts to retard motion.

LEARNING ACTIVITIES: Grades 5-6

Overcoming Friction. Students pull a flat-bottomed mass across various surfaces, using a spring scale to measure the force required to overcome friction. Students collect data on the distance, time, and force required for each surface and then graph this data. They predict the force needed to move a given object over a specific surface.

At this point, student groups could design an object/surface combination that provides the easiest journey. Next, the student groups list possible ways to reduce the friction (e.g., sand, water, ball bearings, grease or other lubricants). They then design an experiment, graphing the data generated. They compare the graph to determine the best lubricant for this type of movement.

Related Science Standards: 1, 2, 4, 5

Parachute Car. Students use a toy jet car with parachute deceleration to demonstrate air resistance on a moving object. They launch the car and measure distance, time, and surface material. The students graph the time vs. distance for each vehicle to determine the fastest machine and best deceleration. How does the parachute work to slow the car down?

Related Science Standards: 1- 5

LEARNING ACTIVITIES: Grades 7-8

Surface Friction. Once again, model cars are used to investigate the effect of force on the motion of an object. Using a ramp to produce a constant starting speed, students allow a car to roll onto different surfaces and record the “stopping distance” caused by each surface. Surfaces are then listed in order of resistance, and students attempt to explain the force of friction in terms of texture, composition, etc.

Related Science Standards: 1, 2, 5

Indicator 11: Describe the various forms of energy, including heat, light, sound, chemical, nuclear, mechanical, and electrical energy, and how that energy can be transformed from one form to another.

LEARNING ACTIVITIES: Grades 5-6

Energy and Communications Technology. The development of communications technology provides the opportunity for an array of activities that demonstrate energy transfer.

Historical Perspective. Using the Internet or print resources, students research the important telecommunication inventions of the last 300 years and make a time line. They answer questions such as the following:

- Did people from different countries work on similar inventions at the same time?
- What scientific and/or technological principles were incorporated into each device?
- Was the device something completely new, or did it build upon a previous invention?
- What were the societal demands that promoted their development?
- How did our society change as a result of the new technologies?

Electricity Basics. In groups of two, the students work with a series of progressively more complex circuits using DC buzzers to communicate a message. The simplest circuit is comprised of a DC buzzer that is turned on and off by a switch and powered by a battery. The final circuit has two switches and two buzzers, with each switch activating both buzzers. Students diagram each circuit schematically and explain them to the class. Their explanation should identify all the different forms of energy at work in their system—electrical, sound, mechanical, etc.

Other Energy Forms. An extension activity could allow students to design and add more-sophisticated components involving other forms of energy such as light or chemical.

Supporting Educational Research: *Benchmarks*, pp. 81- 86, 193, 199, 293;
Hutchinson, J. & Karsnitz, J. 1994. *Design and problem solving in technology*. Albany, NY: Delmar Publishers, Inc., p. 5.
Related Science Standards: 1-4

LEARNING ACTIVITIES: Grades 5-6

Lewis Latimer. African-American engineer Lewis Howard Latimer developed the process used for manufacturing carbon filaments for the Thomas A. Edison lightbulb. The filament (the very fine, threadlike material in a lightbulb) glows whenever electricity passes through it. A major technological advancement, Latimer's work on the filament made electric lightbulbs safe and inexpensive for ordinary households.

The following activities simulate situations that Lewis Latimer and other workers at the Edison Company might have encountered.

- Students sketch a picture of a flashlight bulb and label the *wire* and the *filament*. They identify the parts of the bulb that are associated with Latimer's investigations.
- Students fold a 30.5 cm (1 ft) by 1.3 cm (1/2 in.) strip of aluminum foil in half and connect one end of it to the negative pole of a 6-volt lantern battery. They tightly wrap the other end around the threads of a flashlight bulb. (They must be sure that the foil does not touch the metal on the bottom of the bulb.) Students carefully form an electric circuit by holding the bulb so that the bottom part of the bulb touches the positive pole of the battery. They explain what is happening in their own words. They investigate what happens if they rearrange the parts of the circuit or add a second bulb.
- Students pour two tablespoons of salt into a saucer and add water to just below the rim. They cut another piece of folded aluminum foil (the same size as they used before) in half. They connect one piece to the negative pole of the battery and connect the other foil strip to the positive pole. Then they hold the battery so that the two strips of foil are in the water. (Caution them not to let the strips touch each other.) Ask the students to explain what happens.

Supporting Educational Research: Higginson, Linda. 1996. “Selling an Energy Source.” *Science Scope*, 19(5), Feb. Madrazo, Gerry. 1993. *Multiculturalism in Mathematics, Science and Technology: Readings and Activities*. Addison-Wesley, pp. 103-106.
Related Science Standards: 1, 4
Related Workplace Readiness Standards: 2.1, 2.2, 2.9, 3.1, 3.3, 4.1, 4.11, 5.1, 5.4, 5.9

- Students fold a 91 cm (3 ft) by 5 cm (2 in) piece of aluminum foil lengthwise three times. They wrap the folded foil strip around a nail in coils, leaving about eight inches of foil free on each end. They then connect each end of the foil strip to one of the poles on the battery. Touch the nail to a paper clip. Explain what happens.
- An electric current produces effects that are thermal, chemical, and magnetic. Latimer used an electric current to make his incandescent lamp work. Ask students to explain which effects Latimer would be most concerned about in the design of the lightbulb.
- Students compare the design of lightbulbs used today and determine which design is most efficient and cost-effective.

LEARNING ACTIVITIES: Grades 7-8

Energy Transfer. In a safe section of the school grounds, students ride bicycles as they identify and explain the types of energy being produced and transferred. For example,

A green plant transformed *solar energy* into *chemical energy*.

Students bodies transformed the chemical energy obtained from food into the heat necessary to maintain their bodies' temperature as well as the *mechanical energy* necessary to move the bike's pedals.

The bike's pedals turn the wheels in an illustration of mechanical energy.

When students apply the brakes, the brake pads rub against the wheels, creating the *friction* needed to slow or stop the bicycle. Any accompanying screeching sound involves *sound energy*. The friction may result in the formation of heat.

Related Science Standards: 1, 2, 4

Mall Physics. For many students, a mall is a popular meeting place. It is also an excellent place to study energy and its transfer. Send the students to the mall with directions to make observations of motion, reflections, and other energy phenomena. Back in the classroom, students discuss their findings and convert their observations to questions. They work in teams to design experiments that they could do to answer these questions. They then return to the mall to investigate these questions.

Possible locations and activities include the following:

- Electric organ store - Students try identical notes separately on two different organs and compare sounds, beats, and musical intervals.
- Elevator/escalator - Students determine average speed and apparent weight changes. When on an elevator they compare the readings on a scale when the elevator is stopped and when it is moving up or down. As an extension they could determine its acceleration and deceleration. While on an escalator, they determine its length and its relative speed when loaded and unloaded.
- Fountain - Students estimate the water flow.
- Mall/store lighting - Students use diffraction gratings to observe and compare spectra of various lighting sources in the mall.
- Energy use - Students make an order-of-magnitude estimate of the amount of electrical energy used to light the entire mall at night and then estimate the cost to light the mall.

- Stairs/human work - Students calculate the number of times they would have to climb the stairs in order to "burn" the energy stored in a food item that can be purchased at the mall. (Assume 100% efficiency of the body and no changes in kinetic energy). As an extension, students compare their own power output while walking up the stairs with their output while running up the stairs.
- Store mirrors - Students observe the images formed in different types of mirrors they find in the mall (e.g., convex observation mirrors, concave makeup mirrors, and multiple clothing store mirrors).
- Windows - Students analyze the glare reflected off a variety of surfaces by orienting Polaroid sunglasses in multiple positions.
- Encourage students to find other examples of physical science in the mall and report on these. They can make comparisons between malls.

Supporting Educational Research: "Shopping Mall Physics", *Science Teacher*, March 1996, p. 37.
Related Science Standards: 1, 2, 4, 5

LEARNING ACTIVITIES: Grades 7-8

Power Plant Role-Play. In this simulation activity, the class pretends that New Jersey is planning to build a new power plant that will supply electricity to an area. Student groups assume the role of various development firms, each trying to promote a particular energy source (e.g., solar, wind, oil, natural gas, coal, tidal, hydroelectric, geothermal, nuclear biomass, garbage incineration). Each student group researches information about their energy source such as

- where it can be found
- how it is obtained and/or processed

The students develop a media presentation to try to sway the voters. The presentation should include the following points:

- advantages and disadvantages of this type of power plant
- the environmental impact
- where this type of plant currently exists
- costs
- diagrams, charts, and graphs supporting the energy source

After the class vote, students hold a meeting to review the success of their presentations.

Supporting Educational Research: Higginson, Linda. 1996. "Selling an Energy Source." *Science Scope*, 19(5), Feb. Madrazo, Gerry. 1993. *Multiculturalism in Mathematics, Science and Technology: Readings and Activities*. Addison-Wesley, pp. 103-106.
Related Science Standards: 1-5
Related Workplace Readiness Standards: 2.1-2.10, 3.1-3.5

Indicator 12: Explain how heat flows through materials or across space from warmer objects to cooler ones until both objects are at the same temperature.

LEARNING ACTIVITIES: Grades 5-6

Heat Transfer. In the following activities, students investigate different aspects of heat transfer.

Present the class with the following situation. Suppose a student wants to make soup for lunch and finds the microwave is broken. What type of pot will heat the soup the quickest? Challenge students to design experiments to compare different types of pots (e.g., aluminum, stainless steel, glass, porcelain) and pot bottoms (e.g., copper).

Students investigate the best methods of keeping their lunch hot or cold. They research how a thermos or an insulated bag works. They then design experiments to show how these work.

Related Science Standards: 1-6, 8, 11
Related Workplace Readiness Standards:
1.1, 2.1-2.9, 3.1-3.15, 4.1-4.11, 5.1, 5.2, 5.4, 5.5-5.9

LEARNING ACTIVITIES: Grades 7-8

Energy Efficiency. In this activity, students will investigate the energy efficiency of different types of houses. They investigate various building materials and how they relate to energy efficiency.

In small groups, students collect and analyze energy efficiency data and determine the relationship of certain variables to the energy efficiency of houses. These variables may include

- color and material of the roof
- the amount of insulation
- the direction the house faces
- the number of exposed windows
- the landscape

Power companies regularly perform energy audits and offer a variety of free energy education resources for schools. Invite a power company representative to speak to the class about energy audits and their typical recommendations to homeowners to improve the energy efficiency of a home. Students can then conduct an energy audit of their own homes and compare with their classmates.

Supporting Educational Research: Campbell, Melvin D. 1990. "Hot or Cold." *Science Scope*, NSTA, Jan.
Related Science Standards: 1-5, 10
Related Workplace Readiness Standards: 1.1-1.3, 1.5, 1.7, 1.9, 2.1-2.10, 3.1-3.15, 4.1-4.11, 5.1, 5.4-5.6, 5.8

Freezing Water. For the longest time, a controversy has existed over which freezes faster, hot or cold water. Students survey 10 people of different ages and discuss the results with the class. They form their own hypothesis and design an experiment to test their hypothesis. Review these designs for safety considerations. Students then perform the experiment at home or in class and discuss the results.

As an extension activity, students calculate the amount of energy needed to freeze the water from the starting temperature.

Supporting Educational Research: Campbell, Melvin D. 1990. "Hot or Cold." *Science Scope,* NSTA, Jan.
Related Science Standards: 1-5, 10, 16
Related Workplace Readiness Standards: 1.1-1.3, 1.5, 1.7, 1.9, 2.1-2.10, 3.1-3.15, 4.1-4.11, 5.1, 5.4-5.6, 5.8

Indicator 13: Explain that the sun is a major source of the earth's energy and that energy is emitted in various forms, including visible light, infrared, and ultraviolet radiation.

LEARNING ACTIVITIES: Grades 5-6

Solar Energy. In this activity, students attempt to discover the best location for siting a garden on the school grounds, based on the availability of solar energy. After learning about solar radiation, they work in groups to design a device that will measure solar energy. Their devices should involve variables such as container type, color, and material to get an approximate measure of the sun's energy, which can be used to compare one location with another. Do the different devices agree on the best location for the garden?

Supporting Educational Research: Sorge, Carmen. 1995. "Capturing the Sun's Energy." *Science Scope*, 18 (8), May.
Related Science Standards: 1-2, 4-7, 10
Related Workplace Readiness Standards: 1.1-1.3, 1.5, 1.7, 1.9, 2.1, 2.2, 2.8, 2.9, 3.1, 3.3, 3.6-3.15, 4.1-4.11, 5.4, 5.5, 5.8

LEARNING ACTIVITIES: Grades 5-6

The Greenhouse Effect. Much of the sun's energy (*solar radiation*) becomes trapped in the atmosphere as *heat*. (Some solar radiation initially is absorbed by the Earth's surface; some is reradiated into the atmosphere but cannot pass out of the atmosphere.) Students can better understand this concept in the following simple activity. They shine a light on two thermometers: one that is enclosed in a stoppered test tube and another that is suspended in air. They compare the temperatures. Like the Earth's atmosphere, glass around the thermometer can trap heat energy. The light rays heat up the air in the tube, which cannot move around as much as the air around the suspended thermometer can.

As an extension activity, a greenhouse works on the same principle. If the glass walls of a greenhouse were covered with black material, it would make the room much hotter. However, because plants need light, glass or another transparent material is needed. Students can investigate the materials that greenhouses are made of and how the temperature and amount of sunlight are regulated. They can build cardboard models or just cover a box with plastic, then design experiments to investigate conditions inside the greenhouse.

Related Science Standards: 1-5, 12
Related Workplace Readiness Standards: 1.1, 2.1-2.10, 3.1-3.15, 4.1-4.11, 5.4, 5.5-5.9

LEARNING ACTIVITIES: Grades 7-8

Energy Technology. This activity focuses on the importance of using energy wisely and preserving energy resources, by asking questions such as the following:

- How have different people and cultures used energy in the past?
- What are the various forms of energy and how are they measured?
- What are the differences between renewable and nonrenewable energy sources?
- What is the energy policy of the United States?
- How is energy converted and utilized to benefit society?
- What could be designed to utilize a renewable energy source in the school, community, or home?

These questions raise issues of scientific fact and provide opportunities for application through technological design and problem solving.

Students conduct an energy audit in which they list (on a spreadsheet) how they use energy (what type of energy and for what purpose) over a 24-hour period. Examples will include energy necessary for the heating/cooling of their environment, transportation, food preparation, personal care, entertainment, and the production of anything they used during the observation period. Next, the students evaluate the degree to which renewable versus nonrenewable energy sources were used and evaluate the environmental impact of each identified energy use. Students interview a person from a previous generation to determine how energy use has changed.

Supporting Educational Research: *Benchmarks,* p. 194
Related Science Standards: 1-4, 9

Energy Conservation. Students brainstorm ideas for reducing their dependence on nonrenewable energy sources (e.g., use less, conserve, or change to a renewable source). Selecting from the best brainstorming ideas, students will engage in technology by designing and making/modeling items for an improved energy utilization in their school, home, or community.

For example, they can

- design solar heaters or ovens
- reduce air infiltration
- plan for carpooling
- suggest a sweater/sweatshirt day and lower building temperatures
- develop a system to reduce unnecessary lighting
- design new line of clothing
- develop a system that automatically turns off lighting in unoccupied rooms

Supporting Educational Research: *Benchmarks,* p. 194
Related Science Standards: 1-4, 9

Receiving Wavelengths. Challenge students to investigate this statement: "In general, the longer the wavelength of electromagnetic radiation, the larger the detector must be." Students name some common detectors and explain how their size relates to the wavelength they detect. They explain how antennas; (short wave, radio, and television) work in regard to channel numbers. As an extension activity students find out whether the eyes of small insects are sensitive to ultraviolet waves or infrared waves.

When radio waves enter a tunnel (or other long, narrow region) radiation with wavelengths much longer than the width of the tunnel are absorbed more than radiation with smaller wavelengths. Ask students if they would expect AM or FM car radios to fade out more when traveling through tunnels. What about using other devices such as car phones? Students make a model to show what happens to waves in a tunnel.

Related Science Standards: 1-5, 11
Related Workplace Readiness Standards: 1.1, 2.1-2.10, 3.1-3.15, 4.1-4.11, 5.5, 5.8

Indicator 14: Show how light is reflected, refracted, or absorbed when it interacts with matter and how colors appear as a result of this interaction.

LEARNING ACTIVITIES: Grades 5-6

Periscope. Students construct a periscope to look around corners and over objects using paper-towel cardboard tubes and small mirrors. To determine the angles for the mirrors in the periscope, they set up mirrors on tables and use a flashlight to see how light is reflected. Students draw up blueprints and construct their periscopes. They compare the devices to find the best design.

Related Science Standards: 2, 4, 5

Mirrors. In the following two activities, students work with mirrors to study the reflection of light.

- Students determine where to place a mirror (or mirrors) in their room for optimum reflection depending on their height. They also help their parents place mirrors in the bedrooms of the younger children in the family.
- Students design a curved mirror for a fun house to make them small, large, wide, or narrow.

Related Science Standards: 2, 4, 5
Related Workplace Readiness Standards: 1.1, 2.2, 3.1-3.15, 4.1-4.11, 5.1-5.3, 5.5-5.9

LEARNING ACTIVITIES: Grades 7-8

Lenses. Humans often use lenses or benefit from lenses in their everyday lives, many times without realizing it. Prescription eyeglasses and contact lenses, magnifying glasses, microscopes, telescopes, and kaleidoscopes all utilize lenses. Lenses have helped us to see microscopic organisms, thus giving us the understanding necessary to conquer disease. In this activity, students investigate how one of these items work and try to duplicate it by using different lenses. For example, they may build an astronomical telescope to understand how a combination of different lenses operate. As an extension students investigate how lenses are used in the eye, how they are used to correct vision defects, and how cataracts affect vision.

Underwater. Students measure the angle of refraction between a straw (or pencil) and different liquids in a glass. They use this data to explain how different types of mirages are produced. Students relate this to seeing other submerged objects, such as fish in a lake.

Related Science Standards: 1-6, 11, 12
Related Workplace Readiness Standards: 1.1-1.2, 1.5, 2.1, 2.2, 2.5, 2.6, 2.9, 3.1-3.15, 4.1-4.11, 5.7

Indicator 15: Show how vibrations in materials can generate waves which can transfer energy from one place to another.

LEARNING ACTIVITIES: Grades 5-6

Sound Travel through Solids. Sound waves can be transmitted in solids, liquids, and gases by compression waves. In order to illustrate the transmission of sound waves in solids, students construct string telephones. Each group of students uses a different type of material for the string (e.g., cotton, twine, plastic, or wire); all use a plastic mouthpiece and ear pieces. Using a predetermined sentence, phone each group and have them copy the message. Students graph the results (the number of words heard correctly vs. the number of words in the entire message). They can use the results to determine the most accurate string "phone." This activity can initiate a class discussion concerning the history of communication from drum beating to cellular devices.

Sound Travel through a Liquid. Students illustrate the motion of sound waves through water by clicking rocks or using a metallic clicker out of water and under water and comparing the quality of the sound and source.

Related Science Standards: 1-5

Sound Travel through a Gas. To illustrate sound travel in air, students construct a series of 8 to 10 puffed-cereal pendulums suspended from a coat hanger. Then they pluck a stretched rubber band near (but not touching) a pendulum. As the sound waves reach the pendulum, the next pendulum will move and the others will follow.

Students collect data on the distance each pendulum swings. They can vary the distance of the stretched rubber band from the first pendulum and/or vary the intensity of the pluck.

If a tree falls in a forest and no one is there, does it make a sound? This statement could be the focus of a debate in the class or between student groups.

Related Science Standards: 2, 5

LEARNING ACTIVITIES: Grades 7-8

Straw Oboes. Students construct a straw oboe (one per student) making small V-shaped notches (6-8) along a plastic straw at 1.5-cm intervals. They pinch the end of the straw together. The students then blow gently into their straw, opening and closing the notches to change the pitch of the sound. Students with some background in music may be able to identify the note and/or reproduce it with an instrument of their own. A class discussion about the history of wind instruments can follow.

Straw Pipes. Students cut plastic straws into sections to produce musical notes. They construct single pipes for each note, using an entire straw as well as the following fractional cuts: 1/4, 1/2, 8/15, 3/5, 2/3, 3/4, 4/5, and 8/9 of a straw. Each group member will play one or two pipes as the group play a tune for the class.

Related Science Standards: 2, 5
Related Workplace Readiness Standards: 5.3, 5.4

Indicator 16: Explain the mathematical relationship between the mass of an object, the unbalanced force exerted on it, and the resulting acceleration.

LEARNING ACTIVITIES: Grades 9-12

Newton's First Law of Motion. Provide groups of students with a set of four or five identical-looking, labeled boxes that differ greatly in mass by simple multiples, e.g., empty, 1 unit, 2 units, 3 units, 4 units, more than 4 or 5. (Use packing material so that any objects put in the boxes to supply mass don't move around.) Students work cooperatively to experiment with the boxes by pushing or pulling them around on the same surface. They answer questions such as the following:

- Which box is the easiest to move?
- Which is the most difficult?
- How far does each move when given a similar shove?
- How can a similar force be produced consistently?
- How does each box move on a ramp?

After experimentation, the students rank the boxes in order of mass. Next, challenge the student groups to find the mass of each box relative to the others, e.g., the mass of each in terms of the box with the least or most mass. Does the relative mass of each box explain the ease with which it was moved in the first part of the experiment?

Each group uses the results of their experimentation and plans a presentation to the class that includes their answers to the following questions:

- What ranking does the group have for the boxes based upon mass?
- What are the masses of the boxes relative to each other?
- What is the relationship of these masses to the movement of the boxes in the first investigation?

Supporting Educational Research: *National Science Education Standards*. 1996. p. 177.
Related Science Standards: 2, 5, 9
Related Workplace Readiness Standards: 2.2, 2.7, 2.9, 3.1, 3.3, 3.6, 3.10, 3.12, 3.15, 4.2-4.5, 4.9, 5.4, 5.7

Newton's Second Law of Motion. Students propel a dynamics cart with one unit of force, such as one large rubber band, and measure the time required to travel a fixed distance. They double and triple the units of force acting on the cart and then record the time it takes to travel that same distance. Since acceleration is the rate of change in velocity, the students view the decreasing time as increasing acceleration. They compute the changing acceleration ($d = \frac{1}{2}\ at\ 2,\ a = 2d/t2$). They can then graph the acceleration as a function of the changing force, thus verifying the direct relationship between the acceleration and the unbalanced force.

Students also explore the relationship between the acceleration and the mass of an object when the unbalanced force remains constant. They use a fixed amount of force, such as one large rubber band, and measure the time it takes the dynamics cart to travel a fixed distance. They double and triple the original mass and detect the increasing time (and therefore the decreasing acceleration). To show the inverse relationship, they calculate the acceleration and graph it as a function of the changing mass. They can also graph acceleration as a function of the reciprocal of the mass values to show this relationship. Spreadsheet or graphing programs can improve their curve-fitting and make the analysis easier and more interesting.

Supporting Educational Research: *National Science Education Standards*. 1996. p. 177.
Related Science Standard: 5
Related Workplace Readiness Standards: 2.8-2.10, 3.12-3.15

Indicator 17: Prove that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object.

LEARNING ACTIVITIES: Grades 9-12

Newton's Third Law of Motion. Pairs of students experiment on free-rolling chairs by pushing off of each other's feet or tugging on a rope between them. Trials should vary to include students of similar mass as well as students whose masses vary greatly. The students record the speed and distance traveled by each student. They note whether a given student (or pair of students) travels the same distance each time. They brainstorm ways to standardize the push/tug.

The class records observed and measured data and uses this data to answer questions such as the following:

- Is it possible for one of the objects to experience a larger or smaller force than the other?
- If the forces are the same magnitude, why do the students move at different speeds and to different distances?

Supporting Educational Research: *National Science Education Standards*. 1996. p. 177.
Related Science Standards: 1, 2, 5, 9
Related Workplace Readiness Standards: 3.1-3.3, 3.6, 3.7, 3.9, 3.12, 4.2, 4.9, 5.3, 5.4, 5.7

Next, students of different masses push off of a wall. Other students record the speed and distance traveled by each student. They note whether a given student travels the same distance each time. They brainstorm ways to standardize the push. The class uses this data to answer questions such as the following:

- If the forces are the same, why do the students move at different speeds and to different distances?
- What is the relationship between the student's mass, the speed, and distance? The class designs an experiment to test their ideas about mass, force, and motion. The goal is to collect and graph data to illustrate the relationships between these quantities.

Two variations of the above activity are listed below:

- Students carry out similar experiments with objects of various mass attached by a spring on an air table, air track, or some other low-friction surface. They use the spring to push or pull the objects from rest.

- Students fill a plastic or reinforced glass bottle with a mixture of baking soda and vinegar and then lightly stopper it. They lay the bottle on it's side on a low-friction surface or on rollers. (Caution: The reaction builds up gas under pressure!) When the stopper is expelled from the bottle, the momentum of the system is conserved. Students predict the relative distance the stopper and bottle will move based upon their mass and the law of conservation of momentum.

Supporting Educational Research: *National Science Education Standards*. 1996. p. 177.
Related Science Standards: 1, 2, 5, 9
Related Workplace Readiness Standards: 3.1-3.3, 3.6, 3.7, 3.9, 3.12, 4.2, 4.9, 5.3, 5.4, 5.7

Indicator 18: Know that gravity is a universal form of attraction between masses that depends on the masses and the distance between them.

LEARNING ACTIVITIES: Grades 9-12

Gravity and Distance. Drop an object and ask students why the object fell. They should respond that gravitational force caused the object to fall. Next, drop a larger object of the same composition to demonstrate that a larger gravitational force exists between the Earth and a more massive object. The more massive object does not fall faster or slower than the less massive object, yet it can produce more impact when it hits. A spring balance can be used to measure the gravitational force (weight) between each object and the Earth.

It is more difficult for students to understand the inverse square law of gravitational force and distance. Demonstrate this important concept with light (since an experiment with gravity is difficult to conduct). Light intensity changes inversely to the square of the distance from the source. Use this phenomenon as an analogy for the way gravitational force changes.

To illustrate this concept geometrically, draw one point representing a light source with a rectangular area at one distance unit and a second rectangular area at two distance units. The second rectangle must be drawn so that four straight lines originating from the light source point are connected to all four vertices of both rectangles. It should become clear that the area of the rectangle at two distance units is four times greater than the area of the rectangle at one distance unit, demonstrating that the area increases as the square of the distance from the light source. This means that the intensity of the light at two distance units, covering four times greater area, is only a quarter of the intensity that exists at one distance unit. This will help students relate this concept to gravitation and infer the same inverse relationship for gravitational force and distance.

Supporting Educational Research: National Science Education Standards, p. 177.
Related Science Standards: 2, 9
Related Workplace Readiness Standards: 3.1- 3.3

Indicator 19: Know that electrically charged bodies can attract or repel each other with a force that depends on the size and nature of the charges and the distance between them.

LEARNING ACTIVITIES: Grades 9-12

Electrostatics. Working individually or in small groups, students explore electrostatics with a variety of materials (e.g., simple electroscopes, suspended glass and hard-rubber rods, plastic combs, balloons and bits of paper). Students can charge these materials by rubbing them with wool, hair, or silk. They discover answers to the following questions:

- Does the number of strokes with the charging material affect the strength of the charge?
- Which materials produce charges that attract each other?
- Which produce charges that repel?
- How can the strength of the charge be represented?
- Does the wool, hair, or silk become charged as well as the object rubbed?

In a full-class setting, gather data from the students and use demonstrations to illustrate each important principle. A Van de Graaf generator is a dramatic tool for demonstrations of electrostatics. Other suggested demonstrations include the following:

- Give suspended balloons like or opposite charges and move them closer or further apart to show the relationship between *distance* and *force*.
- Deflect a thin stream of water from a tap with a charged object.
- Suspend or support a large beam of wood on a low-friction pivot and attract it with a charged object.

When there is some humidity, rub a large piece of plastic (PVC) pipe with fur or wool to create a very strong charge. (The other demos work best in low humidity.)

Supporting Educational Research: *Hands-On Physics Activities*, pp. 290-292.
National Science Education Standards, p. 177.
Related Science Standards: 2, 9
Related Workplace Readiness Standards: 2.2, 3.2, 3.7, 3.9, 3.11, 3.12, 4.3, 5.4-5.7

Electrostatics (continued). As extension activities, students cut out paper figures and make them "dance" by attracting them with charged objects. They can investigate how large the figures can be and still be moved with a certain charge.

To illustrate concepts of electrostatics, initiate a class discussion of electrical safety with questions like the following:

- Why are electrical safety devices made out of the materials they are?
- What are safe behaviors in a lightning storm?
- How are home electronics shielded against static electricity?

Supporting Educational Research: *Hands-On Physics Activities,* pp. 290-292.
National Science Education Standards, p. 177.
Related Science Standards: 2, 9
Related Workplace Readiness Standards: 2.2, 3.2, 3.7, 3.9, 3.11, 3.12, 4.3, 5.4-5.7

Indicator 20: Explain the similarities and differences between gravitational forces and electrical forces that act at a distance.

LEARNING ACTIVITIES: Grades 9-12

Gravitational and Electrostatic Forces. In groups, students review their understanding of gravitation and electrostatics. They research answers to the following questions:

- What are some examples in which the electrostatic force is greater than the gravitational?
- What are some examples in which the gravitational force is greater than the electrostatic force?
- What are the visual similarities and differences between the two basic equations - Newton's Law of Universal Gravitation and Coulomb's Law?
- Are there distance limits for these two forces?

The groups report their findings back to the class.

Challenge student groups to compare the electrostatic force and the gravitational force mathematically. Assign each group a pair of objects that will repel electrically and attract gravitationally (e.g., two electrons, two protons, two helium nuclei, or any two simple ions with the same charge). With the help of a spreadsheet program, the students use Coulomb's Law and Newton's Law of Universal Gravitation to compare the forces. They attempt to answer questions such as the following:

- Which force is the stronger force?
- How much stronger is one force than the other?
- What do these findings explain about the way these forces work in everyday life?

Supporting Educational Research: *National Science Education Standards*, p. 177.
Related Science Standards: 3, 9
Related Workplace Readiness Standards: 3.1, 3.2, 4.2, 4.9

Gravitational and Electrostatic Forces (continued). Extensions and variations of the above activity include the following:

- Students investigate the role electrical and gravitational forces play in the lives of stars. What is the relationship between gravitational and electrical forces in a normal star, a red giant, a neutron star, or a supernova? Each of these situations is determined by which fundamental force "wins."
- Students write compare/contrast essays or use a Venn diagram to show the similarities and differences between gravitational and electrical forces.
- Students trace the history of the scientific ideas (and the people who developed them) that led to both Newton's Law of Universal Gravitation and Coulomb's Law.

Supporting Educational Research: *National Science Education Standards*, p. 177.
Related Science Standards: 3, 9
Related Workplace Readiness Standards: 3.1, 3.2, 4.2, 4.9

Indicator 21: Know that the forces that hold the nucleus of an atom together are stronger than electromagnetic forces and that significant amounts of energy are released during nuclear changes.

LEARNING ACTIVITIES: Grades 9-12

Nuclear Physics. Students research the ways that the discoveries of nuclear physics have affected their lives and the lives of people they know. Examples include radiation treatments for cancer, diagnostic tools in medicine, and electricity generated by a nuclear power plant. In teams, students debate the issues regarding the use of nuclear power.

Students make comparisons between the following:

- electromagnetic forces (Coulomb's Equation) and Einstein's theory of mass-energy transfer involving the speed of light
- the kinds of potential energy, such as electromagnetic (solar) energy and nuclear energy
- the forces that hold the electrons to the nucleus

In their study of nuclear reactions, students can use a Geiger counter, a nuclear scaler, or a cloud chamber with a source of alpha and beta emissions. A sealed beta source can be used to expose Polaroid film. Half-life as well as chain reactions can be demonstrated in many ways. Instructors should also discuss terms such as *binding energy* and *mass defect*. An important area in which to engage students is a debate on nuclear power and on researching thermonuclear reactions (fusion). Simulated protocols on the stability of nuclei are readily available and appropriate for this unit.

Supporting Educational Research: *Science Teacher,* Oct. 1992, March 1992, Jan. 1989
Chem Sources. ACS. Vol. 3, pp. 4-31.
Related Science Standards: 1, 3-5
Related Workplace Readiness Standards: 2.5

Indicator 22: Explain how electromagnetic waves are generated and identify the components of the electromagnetic spectrum.

LEARNING ACTIVITIES: Grades 9-12

X Rays. Students compare the effects of X rays on bone, aluminum, and lead. They investigate historical uses of X rays, the amount of X rays a person may have during the year, and new technology that has taken the place of X rays. Students visit with technicians and doctors at local hospitals to learn about the new diagnostic techniques such as *magnetic resonance imaging (MRI)*. They report their findings to the class.

Related Science Standards: 1- 5, 8, 12
Related Workplace Readiness Standards: 1.1, 1.5, 1.7, 2.1-2.10, 3.1-3.15, 4.1, 5.5, 5.6, 5.8

Color. Students investigate the visible range of the electromagnetic spectrum. They try to answer questions such as:

- What determines color?
- Why are some things colored and others not?

They relate the colors of the spectrum to the frequency of light waves.

Students use a spectrophotometer and various filters (e.g., red, blue-green, and yellow) to determine complementary colors and study other examples of transmittance or absorbance. They learn that color arises through the preferential absorption of a fraction of the white light (*electromagnetic radiation*) falling on an object.

Supporting Educational Research: Chem 13 News. 1972-75.
Related Science Standards: 2, 3, 8, 9
Related Workplace Readiness Standards: 1, 5

Uses of Electromagnetic Radiation. Students know about a variety of waves, such as radio and TV waves, microwaves, X rays, gamma rays, infrared waves, and ultraviolet waves. Many of these waves are considered to have potentially dangerous side effects. For example, students see signs in hospitals warning that microwaves are in use. Their parents tell them not to sit too close to the television. They hear that tanning salons are not good for them. X-ray technicians step out of the room when they perform an X ray. They hear people discussing irradiated food.

In this activity, students research the components of the electromagnetic spectrum and make a display of the different types of waves, showing the relative length of each. They also compare the uses of each of these waves as well as safety concerns.

Related Science Standards: 1-5, 11, 12
Related Workplace Readiness Standards: 1.1, 1.3, 1.5, 1.7, 1.9, 2.1-2.10, 3.1-3.5, 4.1-4.11

EMFs. The safety of electromagnetic fields (EMFs) is a controversial topic that has been in the news and has presented a dilemma to scientists and power companies alike. To date, the question remains open as to the harm that strong EMFs pose to living things. A related effect is the impact of strong sources of EMF on the value of nearby real estate.

In teams, students research possible topics such as the following:

- an overview of electromagnetic fields
- EMF research
- epidemiology and EMF
- regulation and EMF
- public reactions to EMF
- media coverage of EMF issues
- the electromagnetic spectrum

Next, students collect data near sources of EMF (e.g., TV set, microwave, stereo, computer). They use a gauss meter to measure the EMF strength at varying distances around each electrical appliance and a graphing calculator to collect and analyze the data. They use their findings to build a mathematical model of the EMF around each device.

Supporting Educational Research: *National Science Education Standards*, p. 177.
Related Science Standards: 2, 5, 12
Related Workplace Readiness Standards: 2, 3, 4

Indicator 23: Explain that all energy is either kinetic or potential and that the total energy of the universe is constant.

LEARNING ACTIVITIES: Grades 9-12

Toys and Energy. Individually or in groups, students work with toys that store energy (e.g., spring-popping toys, jumping discs, wind-up toys, rubber-band toys, battery-operated toys). They address a series of questions:

- What example of kinetic energy did you observe?
- How is the energy stored in this toy (potential energy)?
- At what point is this toy moving fastest (greatest kinetic energy)?

The students record their observations and measurements on a data sheet. They write an explanation of how each toy stores and uses energy, describing the form of energy and the manner in which it is transferred. By comparing the amount of work done on the toy and the work done by the toy the students can calculate the efficiency of the energy transfer.

Several variations of this activity are listed below:

- Students work in groups to investigate an assigned toy, which they demonstrate and explain to the class. The class evaluates their presentation.
- Students write compare/contrast essays or use a Venn diagram to show the similarities and differences between two toys.
- Students design—or design and actually build—a new toy that uses a simple form of energy storage such as a rubber band or a spring.

Supporting Educational Research: *Teaching Science with Toys.* 1994. Middletown, Ohio: Terrific Science Press, pp.187-195
National Science Education Standards, p. 177.
Related Science Standards: 2, 5, 9
Related Workplace Readiness Standards: 2.7, 2.9, 3.2, 3.7, 3.9, 3.11, 3.12, 4.2, 4.3, 4.5, 4.9, 5.4, 5.7

Bouncing Balls. Working in groups, students drop different types of balls to see how high they will rebound. They do research, make observations, and design experiments to answer the following questions:

- When does the ball have potential energy?
- When does the ball have kinetic energy?
- Why doesn't the ball return to the original height?
- What happens to the energy of the ball that is "lost" each time it bounces?

Students can use electronic tools to measure the motion of the objects. The groups share and discuss their findings with the entire class, which then compares the results and forms general conclusions.

Several variations of this activity are listed below.

- Students see how high a squash ball will rebound after it is dropped from a height of one meter. They then place the ball in a hot-water bath (about *60*°C) and repeat the one meter drop. What is different about the kinetic energy of the ball at room temperature and the heated ball? How long does this difference last? (Caution the students to take appropriate safety precautions with the hot water bath.)
- Students use kinematics equations to predict the speed that the balls will have just before they strike the floor. They design a method to measure the speed in order to check their calculations. Students use the difference in height (and potential energy) to calculate the efficiency of the bounce.
- Students experiment with a Ping-Pong™ (ball, a golf ball, a basketball, and a Superball™). Drop the balls individually and stacked (touching) in various combinations on a hard surface. It may take a few moments of practice to get the desired effect. What causes the "blast-off" effect that is observed with the stacked balls? Which combination will produce the greatest height?

Supporting Educational Research: *National Science Education Standards*, p. 177.
Related Science Standards: 2, 9
Related Workplace Readiness Standards: 3.1- 3.3

Heat Exchange. Ask the class these two fundamental questions in thermodynamics:

- Which way does the heat energy flow, from the hot to the cold or from the cold to the hot?
- Is the energy conserved?

In cooperative learning groups, students design their own experiments to test their hypotheses. For example, they may create two separate systems of thermal energy, one with hot water and the other with cold water. They would then connect the two systems with a metallic conductor to allow the heat energy to exchange between two systems and attach a thermometer or heat probe to each system. They may even attempt to create a "closed system" that encloses both the hot and cold reservoirs of energy. Advise the students to insulate the thermal system to minimize the heat loss. Encourage them to make any necessary assumptions about the conservation of energy. Evaluate the students' design, and suggest how they can improve their experimentation.

Students then conduct their experiments and collect data. They use a spreadsheet program to organize and analyze their data. They compute the heat energy lost and gained, generate a mathematical equation that models the heat exchange between the hot and cold systems, and predict how long it will take for the two systems to reach an "ideal" equilibrium state (or the same temperature) and how long it will take to reach the final state.

In a written laboratory report, the students present their hypotheses, data, analysis of data, computational work, conclusions, and ideas for further investigation. Encourage the students not only to present their answers to the questions but also to evaluate the strengths and weaknesses of their claims, arguments, and data.

Related Science Standard: 5
Related Workplace Readiness Standards: 2.7-2.9, 3.6-3.12

SCIENCE STANDARD 10

All students will gain an understanding of the structure, dynamics, and geophysical systems of the earth.

INTRODUCTION

This standard provides students with the skills and understanding needed to interpret their geophysical surroundings, explaining the origin and composition of the planet on which they live and the weather systems generated by a dynamic atmosphere.

They relate the nature of the Earth's crust to surface features that are readily observable. The geography and geology of New Jersey and the rest of the world is explained in terms of tectonic processes, mountain building, water erosion, glaciation, and changes in ocean level as learners acquire and use investigative skills to identify the effects of such processes anywhere on the globe.

The dynamic interrelationship between the ongoing changes in the planet's surface, its oceans, and its atmosphere is linked to a study of the Earth's climate and weather, including discussions of the impact of weather on human activities.

DEVELOPMENTAL OVERVIEW

In grades K-4, young children need a feel for their surroundings. By studying familiar locations, drawing maps, and experimenting with different types of maps, children become more fully aware of their neighborhoods and then their state, nation, and world. Such experimentation introduces students to symbolic representation and models.

Children need to understand where the materials in their world come from. In age-appropriate fashion, children are introduced to characteristics for identification and separation that can be applied to rocks and minerals. The existence and probable origin of various fossils are introduced as students observe and describe fossils of many different life-forms.

Using the concepts of properties and classification, students in the primary grades begin to observe water and its importance on the surface of the Earth. Because students are affected by weather, they are naturally interested in keeping and examining their own records of weather conditions.

By grades 5-8, the middle school years, students learn to create and use more types of maps, including a variety of map projections. For students in the middle grades, the study of the Earth sciences can introduce processes as well as long-term and large-scale changes. The study of weather becomes systematic and predictive. Earth science facts are related, and systems involving many components are introduced.